Segmented Mirror Adaptive Optics

John M. Rakoczy/ED12
205–544–1431

In its pursuit of excellence in advanced optics, MSFC has been developing a test-bed for adaptive optics technology. Adaptive optics is a key technology in establishing the next generation of large space telescopes, as well as improving performance of existing ground-based telescopes.

A particular challenge in dealing with a large-aperture space telescope is the task of getting a large mirror (from 8 to 20 meters in diameter) up in space. Rather than a single monolithic mirror, smaller mirror segments could be fabricated, launched into space, and assembled on orbit. Initial alignment, phasing, and calibration of a segmented-mirror configuration would require an active control system. Once the segments are aligned, the control system would maintain the desired wavefront despite such disturbances to the telescope as thermal transients and structural vibrations. Here lies the motivation for MSFC to develop an adaptive optics test-bed incorporating the controls-optics-structures-thermal initiative.

The Phased-Array Mirror, Extendible Large Aperture is a f/1.5 Cassegrainian telescope. The primary mirror consists of 36 hexagonal segments, 7 centimeters flat-to-flat, and figured to a sphere with a 1.5-meter radius of curvature. A Shack-Hartmann wavefront sensor is used to measure wavefront tip and tilt. Inductive edge sensors measure relative piston motion. Three

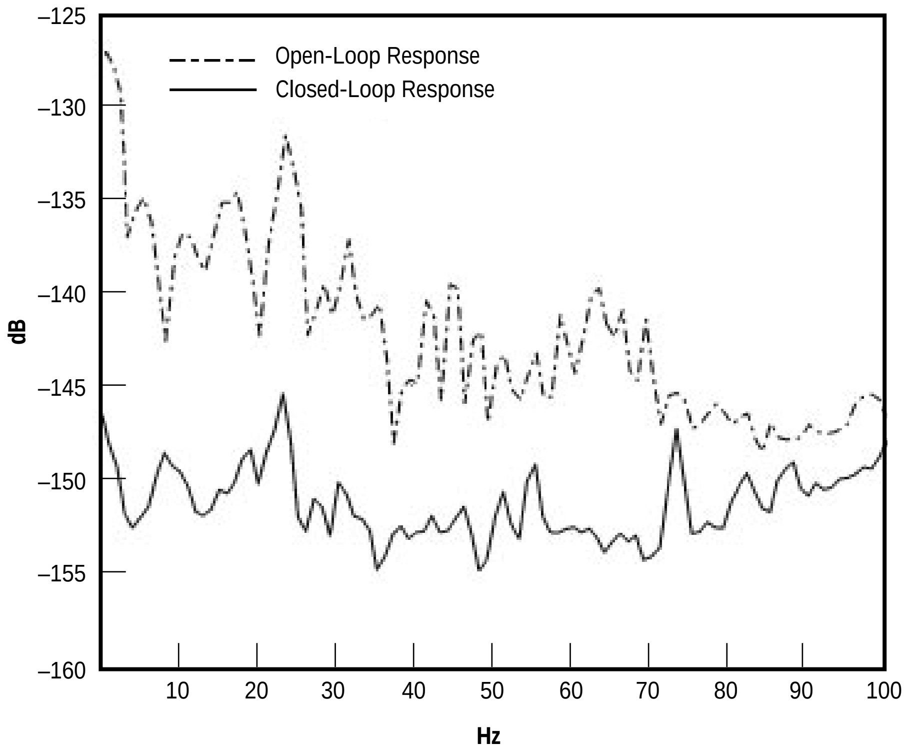

FIGURE 68.—Aberrator plate disturbance power spectral density.

electromagnetic actuators are configured for each segment to effect tip, tilt, and piston motions. Four digital signal processors receive sensor signals, perform control computations, and send actuator commands at a 5,000-Hz sample rate. System components were developed and assembled by Kaman Corporation in Tucson, Arizona. The system was transferred to MSFC in May 1993 when MSFC was tasked with performing integration and testing with funding from the MSFC Center Director's Discretionary Fund.

Program requirements were to control the wavefront of a monochromatic source (helium-neon) to one-tenth of a wavelength at a bandwidth of 100 Hz, which was particularly challenging considering that there were 240 structural vibration modes within the bandwidth of the control system. Furthermore, thermal transients altered the behavior of the wavefront sensors and edge sensors. The effort involved a serious controls-optics-structures-thermal interaction problem.

A control strategy was developed utilizing insights gained from MSFC's Control-Structures Initiative and Large Space Structures Ground Test Facility. (A similar strategy was used in the redesigned Hubble Space Telescope control system in order to accommodate solar array vibration disturbances.) Atmospheric-type disturbances were introduced by mounting a glass aberrator plate on a

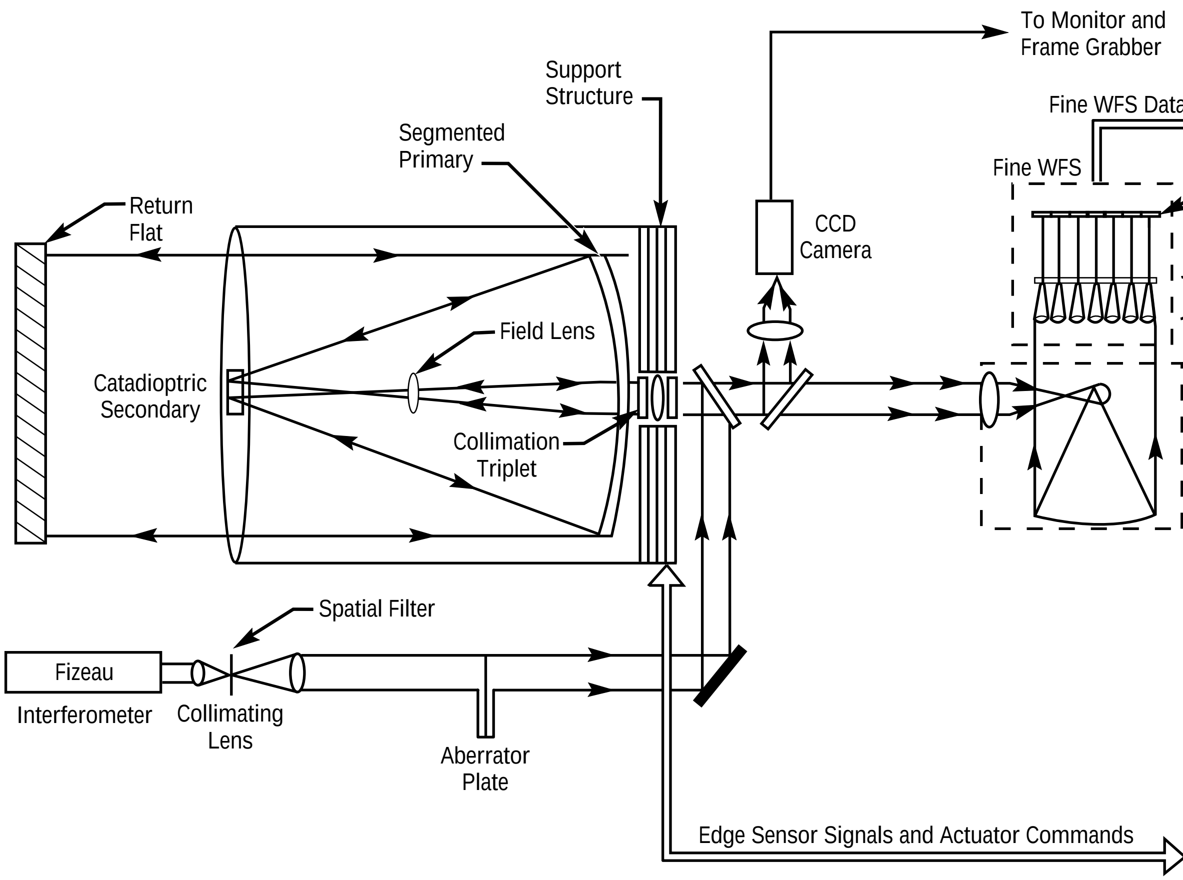

FIGURE 69.—Experimental layout of the system.

motor and rotating it in the optical path of the Phased-Array Mirror, Extendible Large Aperture telescope. Wavefront distortions from the aberrator plate were much more severe than those expected from the atmosphere. Figure 68 shows a power spectral density plot of the aberrated wavefront with and without the control system active. With the completion of this task, MSFC successfully demonstrated the operation of a segmented, primary-mirror adaptive-optics system for tip, tilt, and piston correction up to bandwidths of 100 Hz.

Work is continuing at MSFC to upgrade the system for compatibility with a white light source; specifically, the wavefront sensor will be upgraded for better sensitivity to white light. An automated wavefront sensor calibration and nulling scheme is also under investigation. Absolute distance interferometry is being explored as a way of phasing and calibrating the array in an automatic, turn-key operation. Finally, some of the mirror segments need to be refigured in order to yield better optical performance down to the diffraction limit. When the upgrades are complete, the Phased-Array Mirror, Extendible Large Aperture telescope will be fully operational for visible or infrared astronomy and of possible use as a tertiary component in a major ground observatory.

The success of the integration and testing task depended greatly on a multidisciplinary effort, drawing upon skills from controls, structures, optics, thermal analysis, modal testing, electronics, software, and systems engineering. Team members were awarded an MSFC Research and Technology Group Achievement Award for their efforts in June 1995. The effort will pay high dividends as inputs to future design activities for the next-generation large space telescope. Reference figure 69.

Gleckler, A.; Ames, G.; Markason, D.; Radau, S.; and Waites, H. March 13–18, 1994. Phased-Array Mirror, Extendible Large Aperture: Progress Report on a 0.5-Meter-Diameter Telescope with a 36-Segment Adaptive Primary Mirror, #2201–95. Society of Photo-optical Engineers: Astronautical Telescopes and Instruments for the 21st Century, Kona, Hawaii.

Ames, G.; Howard, R.; Lindner, J.; Montgomery, E.; Patterson, A.; Rakoczy, J.; Zeiders, G.; and Waites, H. February 4–10, 1995. Phased-Array Mirror, Extendible Large Aperture: Phase I Testing and Verification on a 0.5-Meter-Diameter Telescope With a 36-Segment Adaptive Primary Mirror. Society of Photo-optical Engineers: Photonics West 1995, San Jose, California.

Sponsor: Center Director’s Discretionary Fund

Industry Involvement: AmDyn Corporation, Blue Line Engineering, Kaman Aerospace Corporation